Orographically Induced Cirrus Clouds East of the Southern Appalachian Mountains

Ryan Ellis NOAA/National Weather Service, Raleigh, NC
Lindsey Anderson North Carolina State University, Raleigh, NC

Motivation

The development of orographically induced cirrus clouds east of the southern Appalachian Mountain chain can result in areas of unanticipated cloudiness downstream from the higher terrain across the Carolinas and Virginia. Both the degree of cloudiness and its impact on surface temperatures can have an adverse impact on forecast accuracy. This study will attempt to quantify the conditions necessary for orographic cirrus development across the southern Appalachian Mountains. This study will also evaluate null events of orographic cirrus when atmospheric conditions are conducive for cirrus development but none occurs. A case study will be presented from October 2008 illustrating a classic orographic cirrus event and its impacts on local forecast variables.

Data and Results

A total of 24 unique cases of orographic cirrus were observed in part I of the experiment along the southern Appalachians from March 2009 through February 2010. A total of 43 unique cases were observed in part II of the experiment from September 2011 to April 2012.

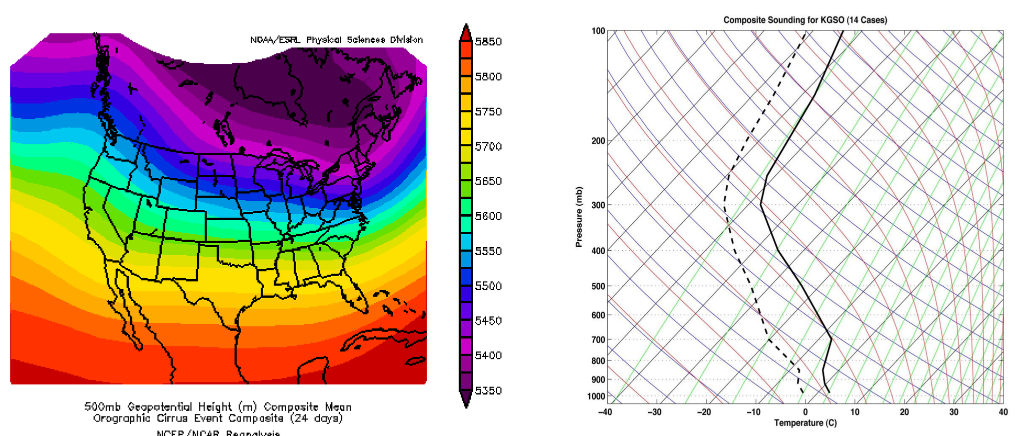

Figure 1: Composite 500 hPa geopotential heights (left) and a composite sounding from all events observed during part I of the experiment at the KGSO upper air site. Note that averaging the sounding over several events causes detail to be lost in the inversion structure between 850 and 700 hPa.

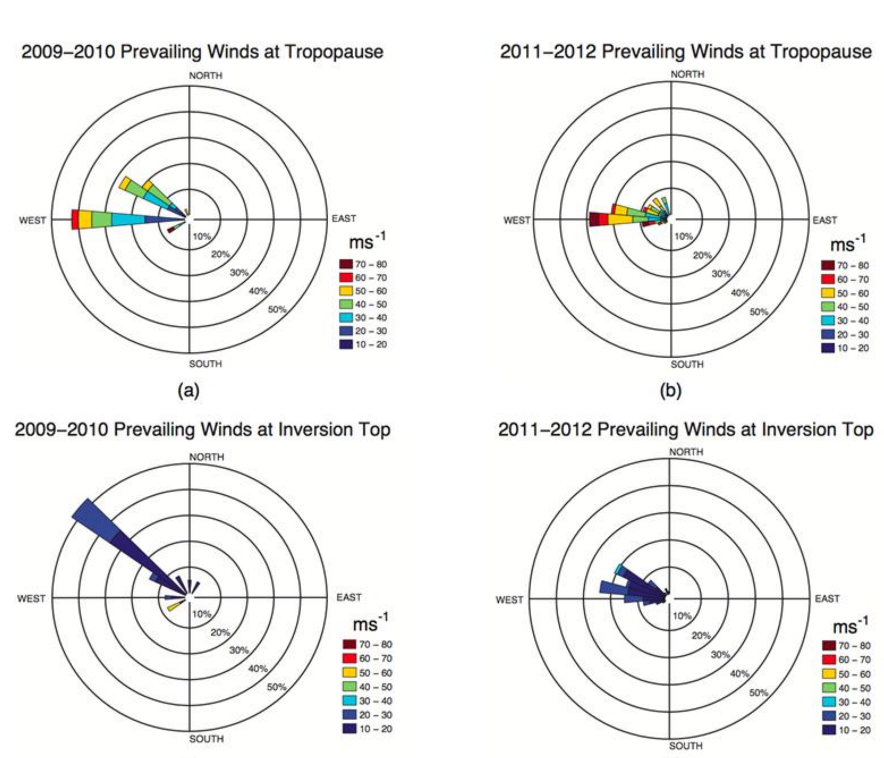

Figure 2: Wind roses for 2009-2010 (left) and 2011-2012 (right). Frequency and strength of wind speed and direction at the tropopause (top) and at the inversion top (bottom).

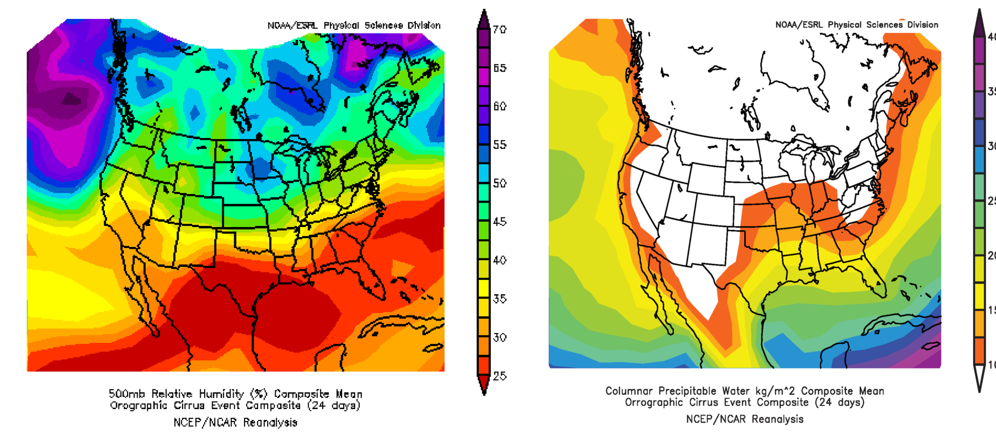

Figure 3: Composite data showing 500 hPa relative humidity (left) and precipitable water (right) from part I of the experiment. Data provides evidence that a pre-existing upstream moisture trigger is needed for orographic cirrus to occur.

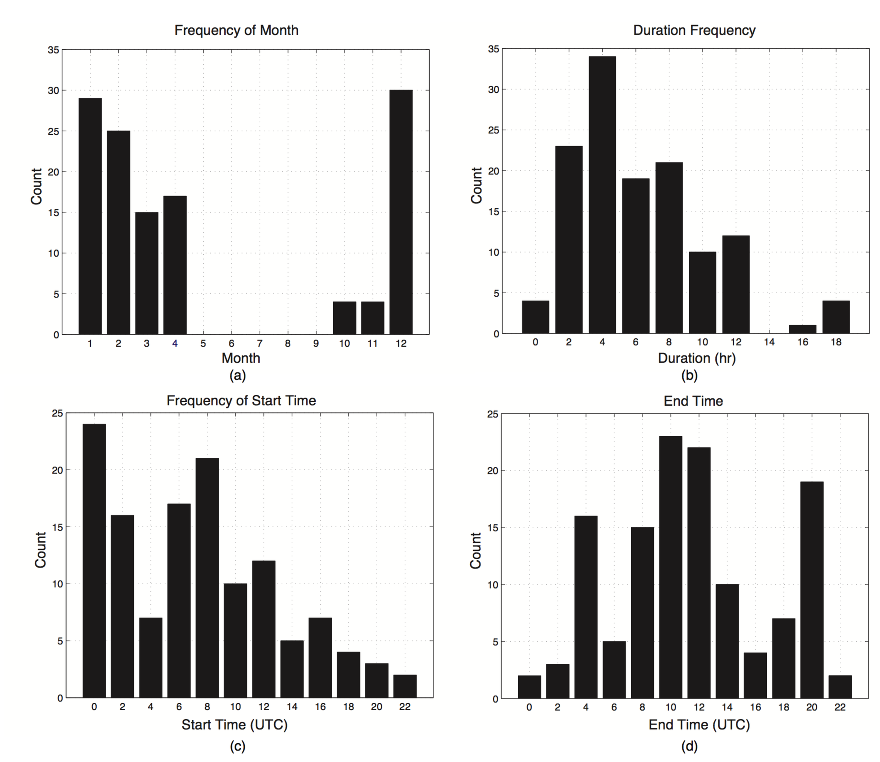

Figure 4: Frequency of orographic cirrus events by month (a), duration (b), start time (c), and end time (d).

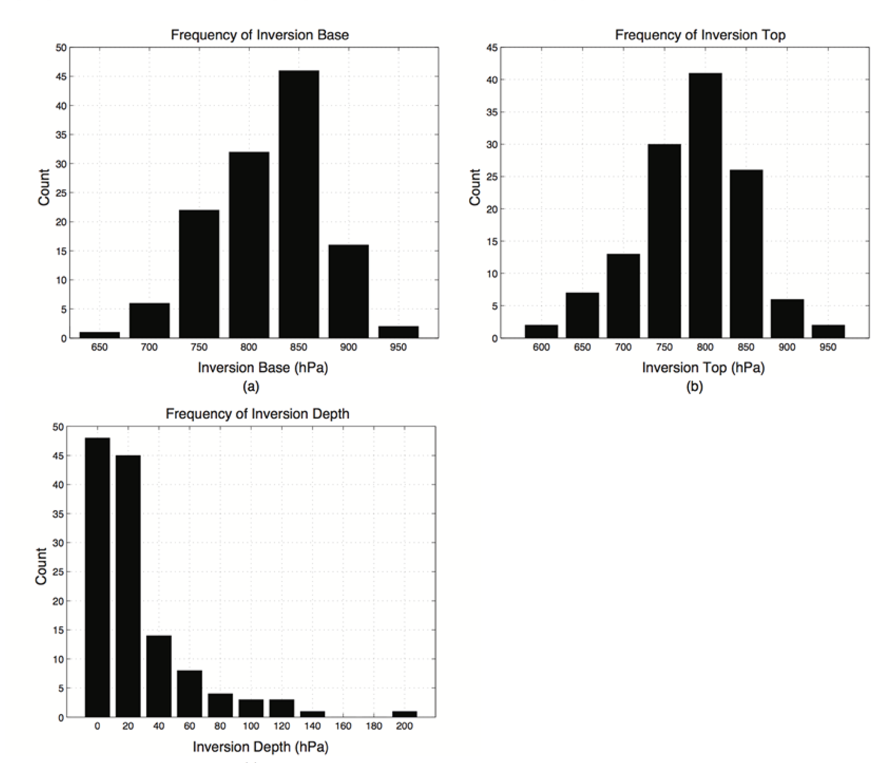

Figure 5: Histograms showing cirrus event inversion statistics including inversion base (a), inversion top (b), and depth (c).

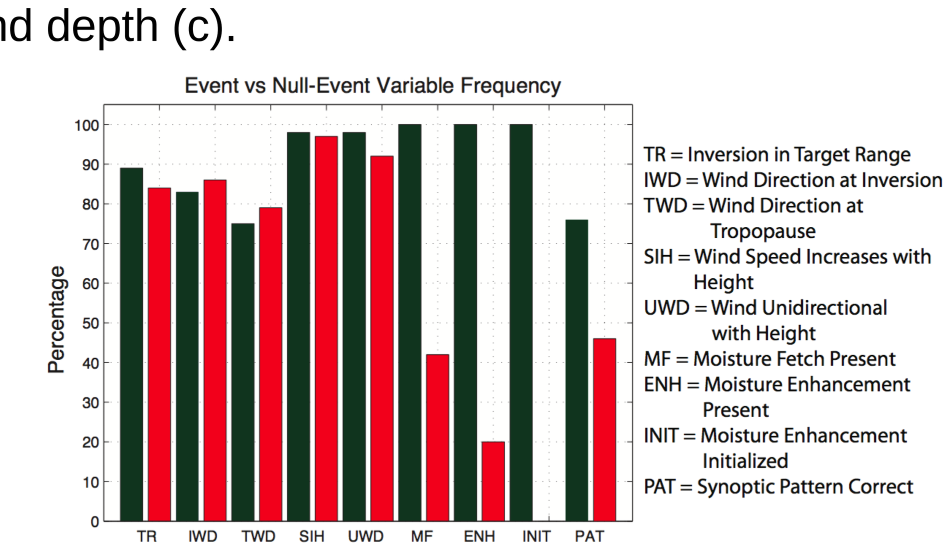

Figure 6: Variable frequency for events (red) and null-events (green) of orographic cirrus during part II. Data suggests that atmospheric sounding data alone is not sufficient to diagnose orographic cirrus events. Satellite data is vital to accurately forecast cirrus events.

Case Study: 29 October 2008

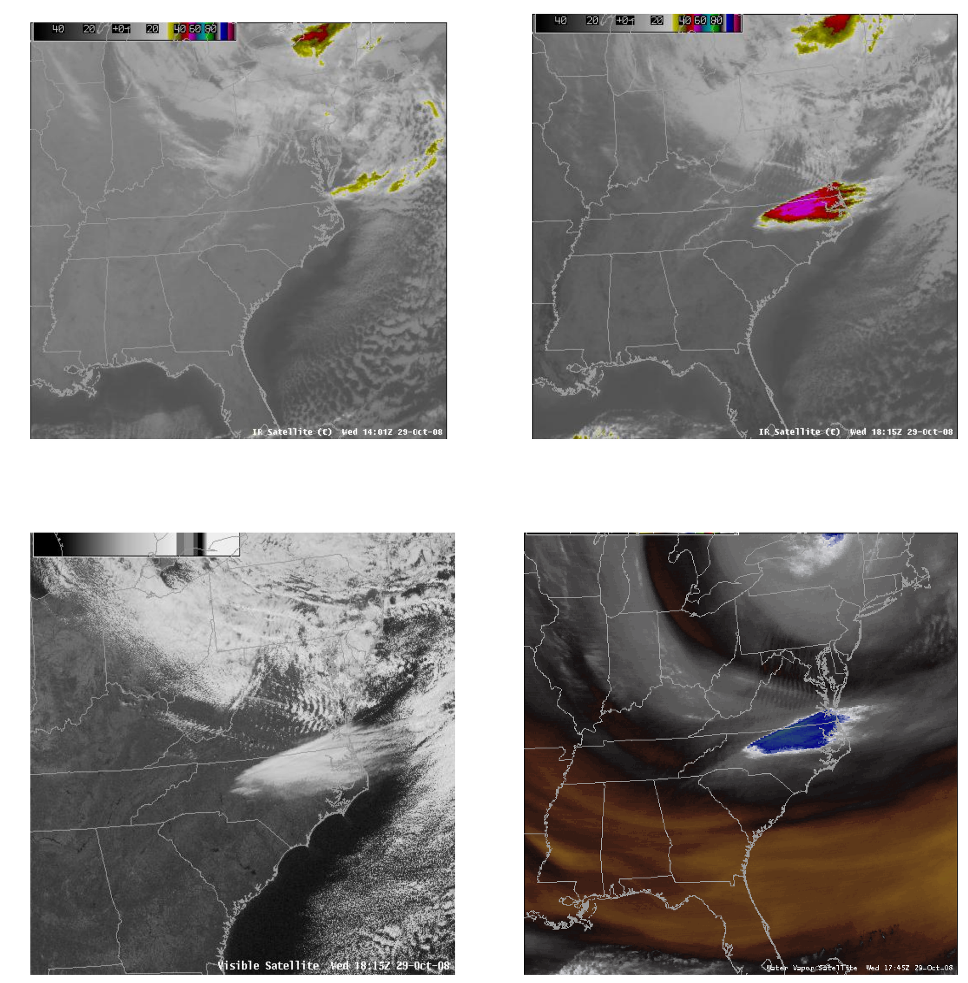

Figure 7: Orographic cirrus outbreak on October 29th, 2008 as seen from GOES satellite imagery including 1400 UTC (top left) and 1800 UTC (top right) infrared images from before and after the onset of the outbreak. Also included are the 1800 UTC visible image (bottom left) and 1800 UTC water vapor image(bottom right).

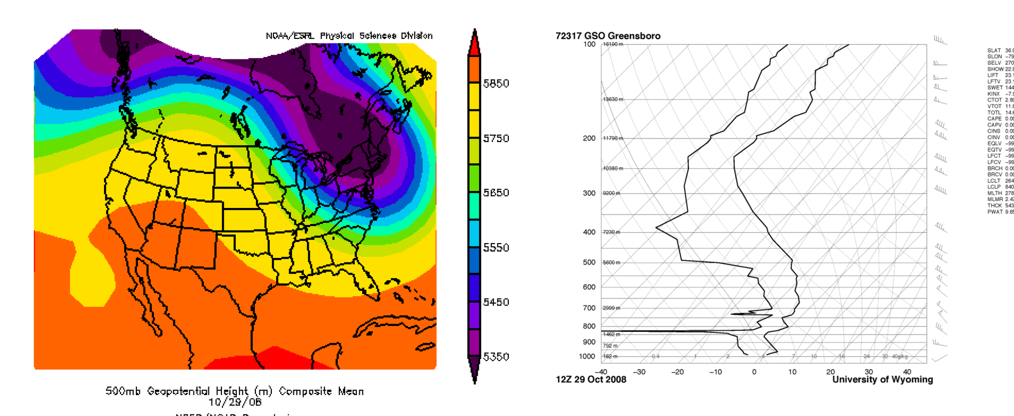

Figure 8: Composite of 500 hPa geopotential heights (left) and 1200 UTC sounding from KGSO (right) from 29 October 2008 showing the environmental conditions present during the orographic cirrus outbreak.

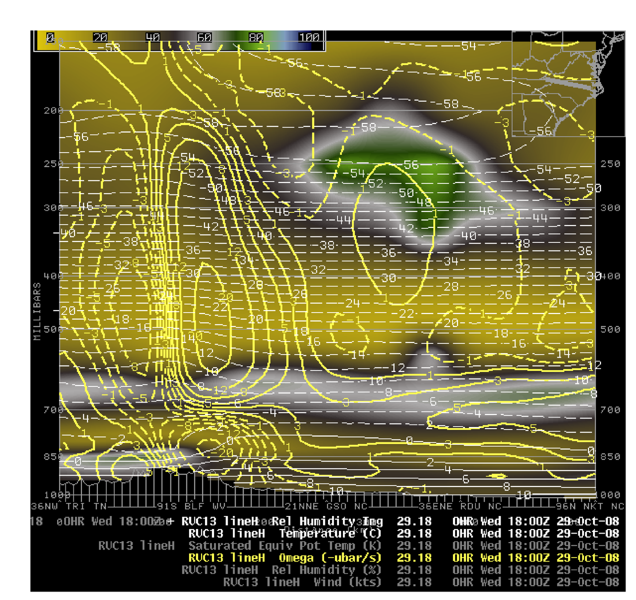

Figure 9: 1800 UTC RUC13 analysis cross section of relative humidity (shaded) with omega (yellow contours). Cross section is oriented across the outbreak over northern North Carolina. Good upward motion is seen just to the northwest of where the outbreak initiates.

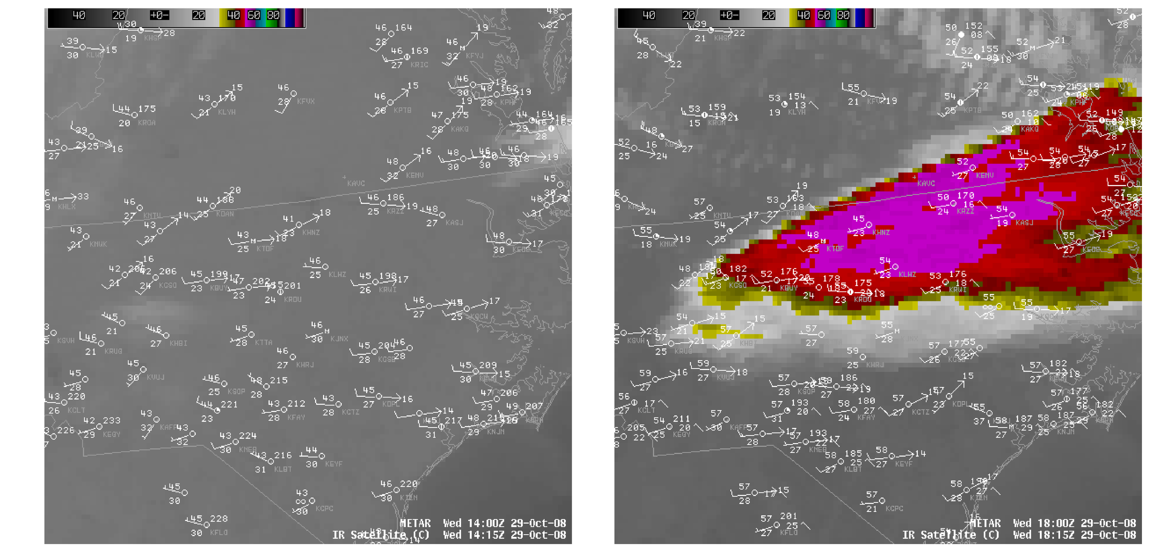

Figure 10: METAR plots overlaid on GOES infrared satellite images from 1400 UTC (left) and 1800 UTC (right). Station observations from underneath the cirrus shield show temperature differences on the order of 10˚F from those observations not under the cirrus shield. It is clear from the 1400 UTC image that these temperature differences were not present prior to the onset of the outbreak.

Conclusions

- Orographic cirrus outbreaks can affect temperatures by as much as 10˚F.
- Outbreak events usually set up in a stable environment with a mid to upper-level low pressure system to the northeast and a strong upper level ridge to the west.
- An inversion typically exists between 850 and 700 hPa.
- Winds are generally unidirectional from the northwest with some slight backing throughout the profile from the top of the inversion to the tropopause.
- A pre-existing upper-level upstream moisture source is usually necessary to trigger the onset of an orographic cirrus outbreak.
- Orographic cirrus events most frequently occur in the cool season, last between 4 and 8 hours, typically begin during the evening or early morning hours and dissipate during the morning or early afternoon hours.
- In addition to forecast and observed soundings, satellite data is a vital component to the process to identify the potential for orographic cirrus.
- An operational forecasting technique for orographic cirrus has been outlined and implemented at WFO Raleigh.

References

1983 Ellrod, G. "Orographic Cirrus Along the Appalachian Mountains," *Satellite Applications Information Note;* **83/2.**

Acknowledgements

I would like to thank Jonathan Blaes for his contributions to this research. Data was provided in part by the NCEP/NCAR Reanalysis and the University of Wyoming.